US TAG Votes on DSRC Standards

ISO balloted 3 DSRC documents as New Work Item Proposals:

- N177 - DSRC Layer 1
- N178 - DSRC Layer 2
- N179 - DSRC Layer 7

Initial ballot by US TAG resulted in "Abstain" for all 3 proposals.

Convener of ISO/TC204/WG15 extended the ballot period to 10/01/96.

US TAG meeting of 09/20/96 resulted in re-ballot.

Second ballot by US TAG resulted in "Agreement with proposal" for all 3 New Work Item Proposals.

APPENDIX E

The Evolution of ITS

The Evolution of ITS

The concept of intelligent transportation dates back almost to the inception of the automobile.[1] Around 1910, before reliable road signs and paper maps were widely available, several enterprising inventors patented and marketed the forerunners to modern electronic route guidance systems. These mechanical guides provided detailed route instructions as a driver passed decision points along the way to a particular destination.[2] For example, the "Live-Map," patented in 1912 by the inventor of the phonograph, consisted of a turntable on a gear train connected to one of the vehicle's wheels.[3] The driver selected one of about 600 paper disks describing certain routes, placed it on the turntable, and set a stylus to the beginning of the route. Each disk was printed with a scale of miles, landmarks and route guidance instructions. As the car drove, the stylus traveled around the perimeter of the disk, pointing out landmarks and alerting the driver when course corrections needed to be made.[4]

Approximately 30 years later, General Motors featured automated highway and vehicle control concepts at the 1939 World's Fair.[5] By the early 1960s, ITS had become a functional reality with installation of the first automated freeway surveillance and control system on Chicago area expressways and the first computer-controlled traffic lights in downtown Wichita Falls, Texas.[6]

The late 1960s and early 1970s ushered in the modern era of ITS, which is based on vehicle communications with infrastructure systems. During this period, the Bureau of Public

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[1] The legacy of ITS can actually be traced back over 2,000 years to the creation of the world's first vehicular navigation system. The Chinese "south-pointing chariot" had a figure with an outstretched arm mounted on the roof that pointed south regardless of the chariot's direction. Invented 1,200 years before discovery of the magnetic compass, the south-pointing chariot operated by a set of odometers mounted on wheels on either side of the chariot. As the vehicle turned, the outer wheel traveled farther than the inner wheel by a distance equal to a fraction of the change in heading. A gear train driven by the chariot's outer wheel engaged during turns and rotated the figure's turntable-base just enough to offset the change in heading. *See* French, R.L., "The Roots of Automobile Route Guidance" at 13, IV ITS QUARTERLY No. 2 (Spring, 1996) ("*Roots*").

[2] *Id.* at 14.

[3] French, R.L., "In-vehicle Route Guidance in the United States: 1910-1985" at 7, *Proceedings, IEE International Conference on Road Traffic Control*, London, England (April 1986).

[4] *Roots* at 14-15.

[5] French, R.L. *et al.*, *A Comparison of IVHS Progress in the United States, Japan & Europe Through 1993* at 17 (March 31, 1994) ("*Comparison*").

[6] *Id.*

Roads in the Department of Commerce (FHWA's predecessor) began exploring how evolving electronic communications systems could be used to improve the safety and efficiency of highway travel. This initiative spawned development of several innovative applications including:

- a modern-day route guidance system that would direct drivers on an in-vehicle monitor to the best physical route based on real-time traffic conditions;

- an urban traffic control system that would allow a central mainframe computer to synchronize the timing and operation of traffic lights in a region; and

- a passing aid system, specifically designed for rural, two-lane driving, that would detect oncoming traffic and signal to a driver when it was safe to pass the vehicle ahead.[7]

These and other Bureau of Public Roads initiatives were field tested around the country with stunning success, prompting industry and universities to begin pursuing their own ITS research.[8]

This spate of activity culminated with a Department of Transportation report to Congress in 1971 that sought "to provide alternatives to continued proliferation of conventional highways."[9] The report recommended (1) additional funds for R&D into automated highway concepts, and (2) legislation for a "Post Interstate Highway Program" that would enable highways to accommodate automated operation.

Progress in ITS implementation continued to be made during the 1970s and early 1980s. FHWA worked with the Department of Interior and the FCC during the late 1970s to establish the Traveler's Information Service, which provides "noncommercial voice information pertaining to traffic and road conditions, traffic hazard advisories, directions, availability of lodging, rest stops and service stations" on 530 and 1610 kHz.[10] Technological breakthroughs made during this period also helped advance ITS. During the 1970s, the Department of Defense developed its satellite-based Global Positioning System ("GPS"). Today, ITS applications of GPS, including vehicle navigation and location monitoring,

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[7] Appendix D of *Comparison* at 12-13.

[8] For example, GM and the Radio Corporation of America co-sponsored early studies on the feasibility of an automated highway system around this time. *Id.* at 13.

[9] *Id.* at 14.

[10] *See* Report and Order, Docket No. 20509, 42 Fed. Reg. 31594 (June 22, 1977).

represent the largest potential markets for GPS receivers.[11] In addition, the Bureau of Census began using digital maps for processing census information.[12] The map encoding concepts developed by the Bureau enabled the development of road map databases, which are used today in automobile navigation and guidance systems, traffic management centers and fleet dispatch offices.[13]

By the mid-1980s in the United States, traffic congestion had become a critical urban issue, increasingly costing lives and billions of dollars in lost productivity. State departments of transportation also began to realize during this period that further road construction would not alleviate traffic congestion problems. The California Department of Transportation ("Caltrans") responded by organizing a conference in October, 1986 to examine ITS as an alternative to road-building to ameliorate congestion.[14] The Caltrans' conference rekindled widespread national interest in ITS and led to the eventual formation of ITS America.

Following the Caltrans conference, a core group of about 20 attendees from government, academia, and industry continued to meet and discuss ITS issues. This group evolved into "Mobility 2000" -- an ad hoc management committee that fueled the growing interest in ITS by organizing several follow-up conferences in 1988 and 1989.[15] By 1990, interested parties had recognized the need for a more formal and permanent organizational structure to coordinate ITS development and deployment. In August of that year, ITS America (then IVHS America) was born.[16]

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[11] *Comparison* at 19.

[12] *Id.*

[13] *Id.*

[14] Appendix D of *Comparison* at 16.

[15] *Comparison* at 30.

[16] *Id.*

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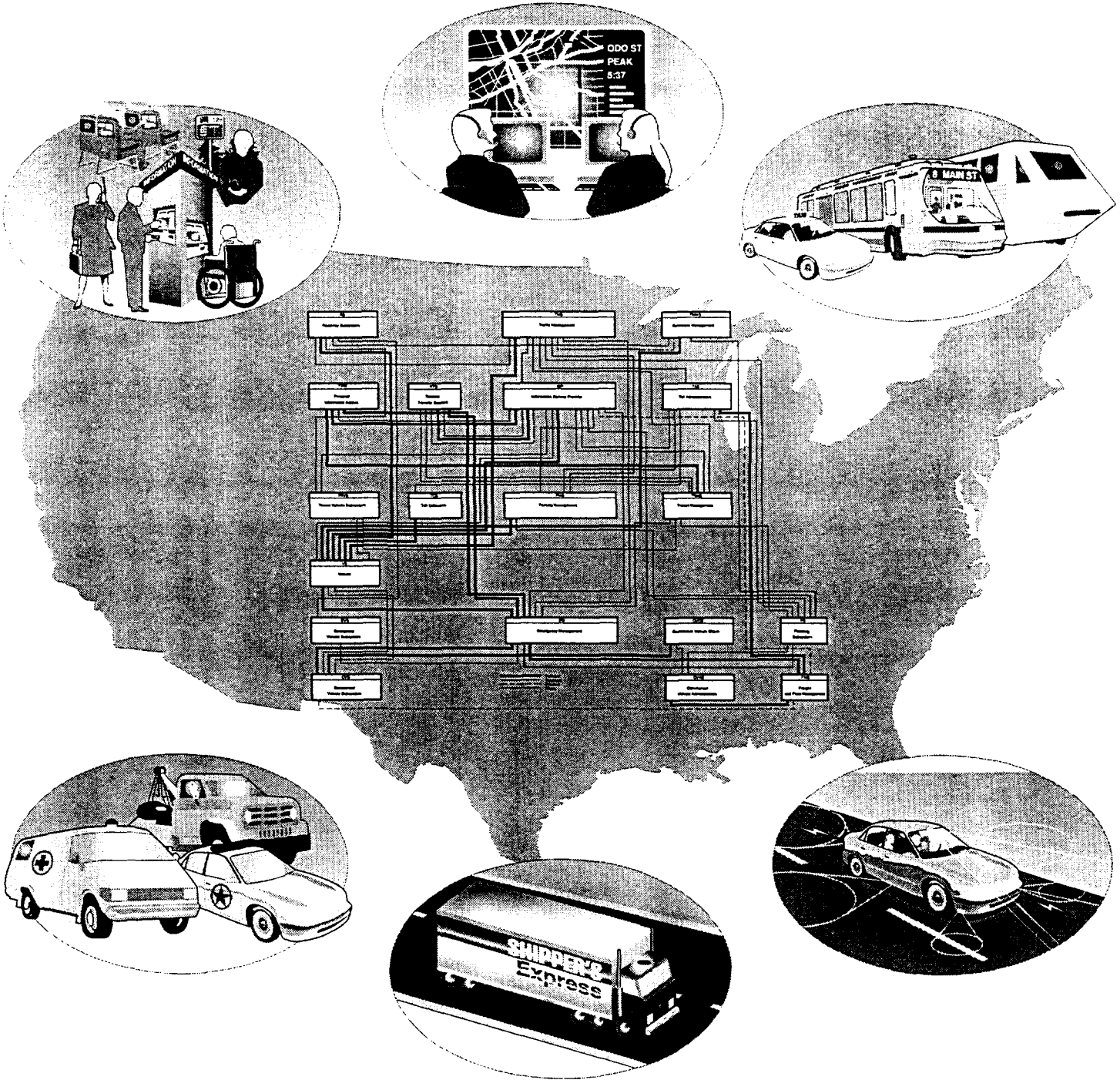
APPENDIX F

U.S. Department of
Transportation, Federal
Highway Administration,
ITS Architecture:
Executive Summary
(June, 1996)

US Department
of Transportation
Federal Highway Administration

ITS Architecture
Executive Summary

JUNE 1996

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) OPPORTUNITY

Although the United States has one of the best surface transportation systems in the world, the mobility we as Americans prize so highly is threatened by the continuing growth in travel demand. In many areas of the country, we no longer have the option to build additional roadways to meet this increasing demand, due to the lack of suitable land to build on, limited financial resources, and environmental impact issues.

Congestion on the Nation's highways, particularly in urbanized areas and along heavily traveled inter-city corridors, is exacting a toll on our pocketbooks, our quality of life, and our environment. In a recent report published by the Texas Transportation Institute on urban mobility in 50 urbanized areas (e.g., Los Angeles, Washington, D.C., Miami, , etc.), it was estimated that for 1992, the total cost (delay plus wasted fuel) due to congestion for the areas studied was $48 billion, approximately 89 percent of that attributable to delay. This represented a nine percent increase over the economic impact of congestion calculated for 1991. Washington, D.C., had the dubious honor of ranking number one with a "congestion tax" of $820 per person and $1580 per registered vehicle. Despite the increasing delays due to congestion, of the 88 percent of all U.S. workers who drive to work, 76 percent drive alone, 12 percent use car pools, and only 5 percent use mass transit. In fact, the United States, with an average of 1.3 occupants per vehicle, has the second lowest occupants per vehicle rating in the world behind San Marino.

Safety on the nation's surface transportation system is also a concern. Preliminary 1993 estimates indicate there were 40,115 people killed and another 3 million injured in traffic accidents involving automobiles. While most accidents are urban, sixty-one percent of all fatal accidents are reported to occur in rural areas. Even though highway fatalities have leveled off in the past few years, it is astounding that we can so blithely accept the loss of so many lives when technology could save many of them.

In addition to the basic problems of congestion and safety, there are the "niche" problems of inefficiency and loss of productivity. These range from a frustratingly simple one of finding a parking place, or knowing that none are available without having to look for twenty minutes, to having to stop to pay tolls. Relative to commercial

Transportation Element	United States	Next Closest
Roads	3,904,721 miles	1,342,000 miles (India)
Registered Automobiles	146,314,000	40,772,407 (Japan)
Cargo Shipped by Road (in million ton-miles)	815,014	278,806 (China)
Cargo Shipped by Rail (in million ton-miles)	1,183,000	853,576 (China)

The United States' surface transportation system is one of the best in the world. Safe, efficient, environmentally responsible transportation is vital to the social and economic well being of the nation.

vehicle operations, the productivity of trucking is eaten into by stops for weighing, for inspections, or to verify compliance with regulations. Since transportation is an integral part of nearly all of industry's productive and distributive processes, a penalty to transportation productivity is a penalty to national productivity. We should and can do better.

There is no single answer to the set of complex transportation problems that face the nation. However, new technologies in computing, sensing, and communications, commonly referred to as ITS technologies, are opening up new possibilities that collectively can go a long way. Some of these are better ways of doing old things, like traffic control, but some are entirely new, such as dynamic route guidance. Most are ideas that transportation professionals have had for a long time, but were beyond the available technology or cost too much as individual bits and pieces.

ITS technologies have been encapsulated in a collection of interrelated user services for application to the nation's surface transportation problems. To date, twenty-nine user services have been identified. This list of user services is neither exhaustive nor final. In fact, a thirtieth user service, Highway-Rail Intersection, is currently being developed. The user services have been bundled into six categories as shown below.

User Services Bundle	User Services
Travel and Transportation Management	• En-Route Driver Information + • Route Guidance • Traveler Services Information • Traffic Control + • Incident Management • Emissions Testing and Mitigation • Demand Management and Operations • Pre-trip Travel Information • Ride Matching and Reservation
Public Transportation Operations	• Public Transportation Management + • En-Route Transit Information • Personalized Public Transit • Public Travel Security
Electronic Payment	• Electronic Payment Services +
Commercial Vehicle Operations	• Commercial Vehicle Electronic Clearance + • Automated Roadside Safety Inspection + • On-board Safety Monitoring – • Commercial Vehicle Administration Processes • Hazardous Materials Incident Response • Freight Mobility
Emergency Management	• Emergency Notification and Personal Security • Emergency Vehicle Management
Advanced Vehicle Control and Safety Systems	• Longitudinal Collision Avoidance • Lateral Collision Avoidance • Intersection Collision Avoidance + • Vision Enhancement for Crash Avoidance • Safety Readiness • Pre-Crash Restraint Deployment • Automated Highway System +

ITS User Services

ITS presents stakeholders with a variety of options to address their transportation needs. Left without adequate guidance, stakeholders could easily develop systems solutions to their needs which were incompatible with their regional neighbors. Put another way, if City A choose to implement user services one way, and a neighboring City B another, then it is a real possibility that a motorist/traveler would find that none of the ITS equipment or services purchased for use in City A, would work in City B. To fully maximize the potential of ITS technologies, system design solutions must be compatible at the system interface level in order to share data, provide coordinated, area-wide integrated operations, and support interoperable equipment and services where appropriate. The National ITS Architecture provides this overall guidance to ensure system, product, and service compatibility/interoperability, without limiting the design options of the stakeholder.

NATIONAL ITS ARCHITECTURE

The National ITS Architecture provides a common structure for the design of intelligent transportation systems. It is not a system design nor is it a design concept. What it does is define the framework around which multiple design approaches can be developed, each one specifically tailored to meet the individual needs of the user, while maintaining the benefits of a common architecture noted above. The architecture defines the functions (e.g., gather traffic information or request a route) that must be performed to implement a given user service, the physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle), the interfaces/information flows between the physical subsystems, and the communication requirements for the information flows (e.g., wireline or wireless). In addition, it identifies and specifies the requirements for the standards needed to support national and regional interoperability, as well as product standards needed to support economy of scale considerations in deployment.

Model of ITS Functions (Logical Architecture)

The *Logical Architecture* presents a functional view of the ITS user services. This perspective is divorced from likely implementations and physical interface requirements. It defines the functions or process specifications that are required to perform ITS user services, and the information or data flows that need to be exchanged between these functions. The functional decomposition process begins by defining those elements which are inside the architecture, and those which are not. For example, travelers are external to the architecture, but the equipment that they use to obtain information or provide inputs is inside. In other words, the architecture defines the functions ITS must perform in support of a traveler's requirements, not the functions of the traveler. A financial institution that processes tolls is outside of the architecture, whereas the ITS components that detect vehicles and collect tolls are inside. Existing broadcast media for the transmission of traveler information are outside of the

architecture, but the elements that provide ITS traveler information to the media are inside.

ITS functions are depicted using *data flow diagrams*. A simplified top level data flow diagram is presented below. In a data flow diagram, circles represent functions that are broken down into lower levels of detail on subsequent diagrams. The lowest level of decomposition is a *Process Specification*, e.g., *Detect Roadside Pollution Levels*. This process detects pollution levels present in the environment and passes the pollution measurement data on to another process, *Process Pollution Data*, where it is combined with other such detected data. Both process specifications are within the *Manage Traffic* function. Rectangles represent the external entities defined above. The lines drawn between the functions (circles), and between the functions and the external entities (rectangles), represent data flows. They are further subdivided on subsequent diagrams and are described in a data dictionary.
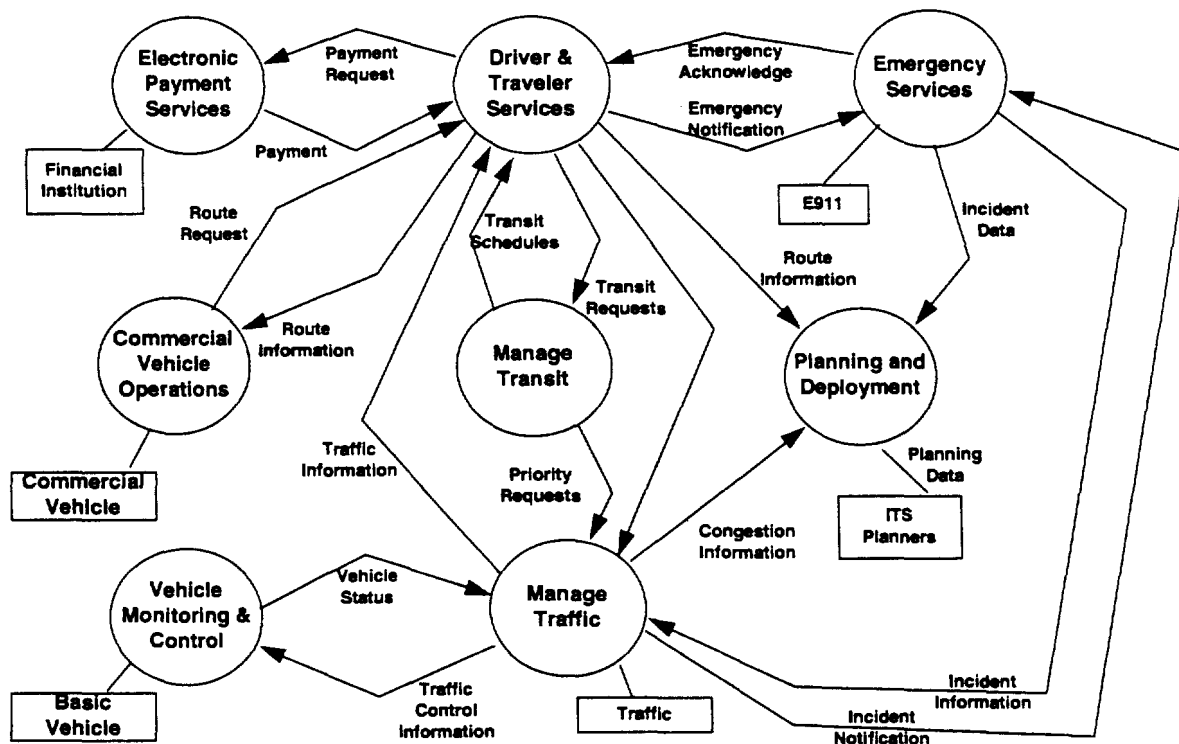
Simplified Top Level Logical Architecture

Model of ITS Physical Entities (Physical Architecture)

The *Physical Architecture* partitions the functions defined by the Logical Architecture into *systems*, and at a lower level, *subsystems*, based on the functional similarity of the process specifications and the location where the functions are being performed. A top level diagram of the physical architecture is shown on the following page.

The physical architecture defines four systems; *Traveler, Center, Roadside,* and *Vehicle,* and nineteen subsystems. The specific choice of nineteen subsystems represents a lower level of partitioning of functions that is intended to capture all anticipated subsystem boundaries for the present, and 20 years into the future. Subsystems are composed of *equipment packages* with specific functional attributes. Equipment packages are defined to support analyses and deployment, and they represent the smallest units within a subsystem that might be purchased.

In deployments, the character of a subsystem deployment is determined by the specific equipment packages chosen. For example, one municipal deployment of a *Traffic Management Subsystem* may select *Collect Traffic Surveillance* and *Basic Signal Control* equipment packages, while a state Traffic Management Center may select *Collect Traffic Surveillance* and *Freeway Control* packages. In addition, subsystems may be deployed individually or in "aggregations" or combinations that will vary by geography and time based on local deployment choices. A Traffic Management Center may include a *Traffic Management Subsystem, Information Provider Subsystem,* and *Emergency Management Subsystem,* all within one building, while another Traffic Management Center may concentrate only on the management of traffic with the *Traffic Management Subsystem.* A discussion of the function of each subsystem is provided on the following pages.
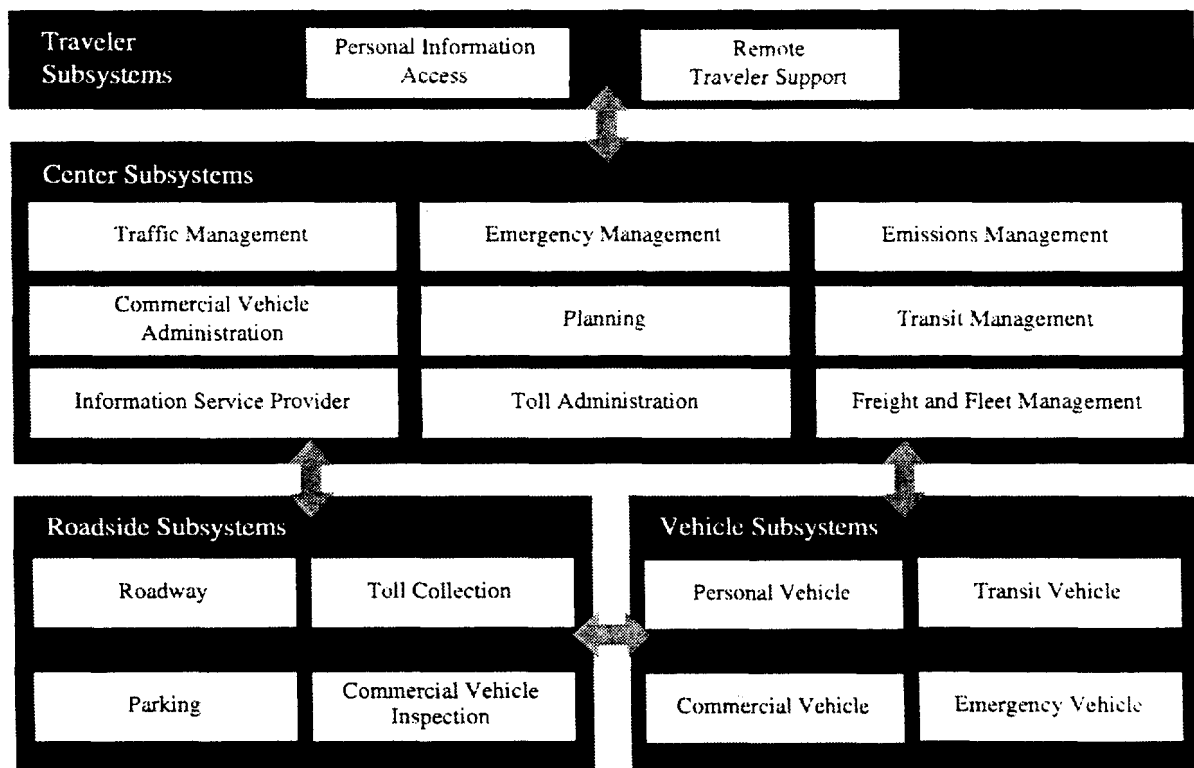
Architecture Systems and Subsystems

Center Subsystems

Center Subsystems deal with those functions normally assigned to public/private administrative, management, or planning agencies. The nine Center Subsystems are described below:

- *Commercial Vehicle Administration* - Sells credentials and administers taxes, keeps records of safety and credential check data, and participates in information exchange with other commercial vehicle administration subsystems and CVO Information Requesters.
- *Fleet and Freight Management* - Monitors and coordinates vehicle fleets including coordination with intermodal freight depots or shippers.
- *Toll Administration* - Provides general payment administration capabilities to support electronic assessment of tolls and other transportation usage fees.
- *Transit Management* - Collects operational data from transit vehicles and performs strategic and tactical planning for drivers and vehicles.
- *Emergency Management* - Coordinates response to incidents, including those involving hazardous materials (HAZMAT).
- *Emissions Management* - Collects and processes pollution data and provides demand management input to Traffic Management.
- *Planning* - Aids in optimal planning for ITS deployment. Collects and processes operational data from other Center subsystems, as well as the Parking Management Subsystem, and provides the results to Transportation Planners.
- *Traffic Management* - Processes traffic data and provides basic traffic and incident management services through the Roadside and other subsystems. The Traffic Management Subsystem may share traffic data with Information Service Providers. Different equipment packages provide a focus on surface streets or highways (freeways and interstates) or both. It also coordinates transit signal priority and emergency vehicle signal preemption.
- *Information Service Provider* - This subsystem may be deployed alone (to generally serve drivers and/or travelers) or be combined with Transit Management (to specifically benefit transit travelers), Traffic Management (to specifically benefit drivers and their passengers), Emergency Management (for emergency vehicle routing), Parking Management (for brokering parking reservations), and/or Commercial Vehicle Administration (for commercial vehicle routing) deployments. ISPs can collect and process transportation data from the aforementioned centers, and broadcast general information products (e.g., link times), or deliver personalized information products (e.g., personalized or optimized routing) in response to individual information requests. Because the ISP may know where certain vehicles are, it may use them as "probes" to help determine highway conditions, levels of congestion, and aid in the determination of travel or link times. This probe data may be shared with the Traffic Management Subsystem. The ISP is a key element of pre-trip travel information, infrastructure based route guidance, brokering demand-responsive transit and ridematching, and other traveler information services.

Roadside Subsystems

These subsystems include functions that require convenient access to a roadside location for the deployment of sensors, signals, programmable signs, or other interfaces with travelers and vehicles of all types. The four Roadside Subsystems are described below:

- ***Roadway*** - Provides traffic management surveillance, signals, and signage for traveler information.
- ***Toll Collection*** - Interacts with vehicle toll tags to collect tolls and identify violators.
- ***Parking Management*** - Collects parking fees and manages parking lot occupancy/availability.
- ***Commercial Vehicle Check*** - Collects credential and safety data from vehicle tags, determines conformance to requirements, posts results to the driver (and in some safety exception cases, the carrier), and records the results for the Commercial Vehicle Administration Subsystem.

Vehicle Subsystems

These subsystems are installed in a vehicle. The four Vehicle Subsystems are described below:

- ***Vehicle*** - Functions that may be common across all vehicle types are located here (e.g. navigation, tolls, etc.) so that specific vehicle deployments may include aggregations of this subsystem with one of the other three specialized vehicle subsystems types. The Vehicle Subsystem includes the user services of the Advanced Vehicle Control and Safety Systems user services bundle.
- ***Transit Vehicle*** - Provides operational data to the Transit Management Center, receives transit network status, provides enroute traveler information to travelers, and provides passenger and driver security functions.
- ***Commercial Vehicle*** - Stores safety data, identification numbers (driver, vehicle, and carrier), last check event data, and supports in-vehicle signage for driver pass/pull-in messages.
- ***Emergency Vehicle*** - Provides vehicle and incident status to the Emergency Management Subsystem.

Traveler Subsystems

These subsystems represent platforms for ITS functions of interest to travelers or carriers (e.g., commercial vehicle operators) in support of multimodal traveling. They may be fixed (e.g., kiosks or home/office computers) or portable (e.g., a palm-top computer), and may be accessed by the public (e.g., through kiosks) or by individuals (e.g., through cellular phones or personal computers). The two Traveler Subsystems are described below:

- **Remote Traveler Support** - Provides traveler information at public kiosks. This subsystem includes traveler security functions.
- **Personal Information Access** - Provides traveler information and supports emergency requests for travelers using personal computers/telecommunication equipment at the home, office, or while on travel.

Communications

The National ITS Architecture provides the framework that ties the transportation and telecommunication worlds together to enable the development and effective implementation of the broad range of ITS user services. There are multiple communications options available to the system designer. The flexibility in choosing between various options allows each implementor the ability to select the specific technology that meets the local, regional, or national needs. The architecture identifies and assesses the capabilities of candidate communications technologies, but it does not select or recommend "winning" systems and technologies.

One of the fundamental guiding philosophies in the development of the National ITS Architecture has been to leverage the existing and emerging transportation and communication infrastructures in its design. This minimizes the risk and cost of deployment, and maximizes marketplace acceptance, penetration, and early deployment.

The architecture has identified four communication media types to support the communications requirements between the nineteen subsystems. They are *wireline* (fixed-to-fixed), *wide area wireless* (fixed-to-mobile), *dedicated short range communications* (fixed-to-mobile), and *vehicle-to-vehicle* (mobile-to-mobile). A top level subsystems interconnect diagram that identifies the communications media interfaces between the architecture's nineteen subsystems is provided on the following page.
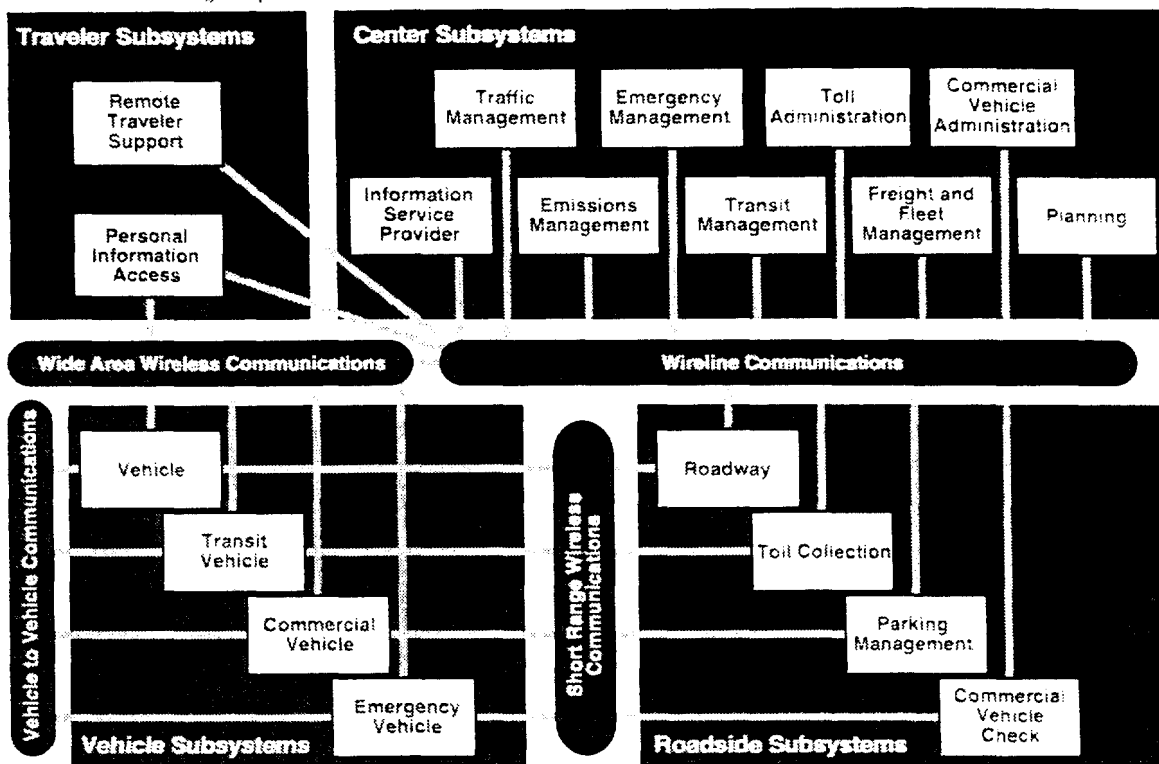
Architecture Subsystems Interconnect Diagram

There are numerous wireline technologies to choose from for fixed-to-fixed communications requirements. For example, the Traffic Management Subsystem can use leased or owned twisted wire pairs, coaxial cable, or fiber optics to gather information and to monitor and control Roadway Subsystem equipment packages (e.g., traffic surveillance sensors, traffic signals, changeable message signs, etc.). In other applications, it may be more advantageous to use terrestrial microwave links, spread spectrum radio, or an area radio network to provide communications between a Traffic Management Center and remote controllers. Although wireless communications technologies, they are used to provide fixed-to-fixed communications in the example cited, consequently the architecture recognizes them as wireline communications media.

The architecture design links the Center Subsystems together over a wireline network. This allows each Center Subsystem to collect, integrate, and disseminate collected information to all other Center Subsystems, resulting in improved interjurisdictional communications and coordination that in turn will directly affect the efficiency and effectiveness of all Center Subsystems operations. Wireline network options include the use of private networks, public shared networks, or a mixture of the two. Private network technologies assessed by the architecture team include Ethernet, Fiber Distributed Data Interface (FDDI), Synchronous Optical NETwork (SONET), and Asynchronous Transfer Mode (ATM). Public shared network technologies assessed include leased analog lines, leased digital lines, frame relay, Integrated Services Digital

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Network (ISDN), metropolitan ethernet, Internet, and Switched Multimegabit Data Service (SMDS).

The architecture identifies two distinct categories of wireless communications based on range and area of coverage. Wide area wireless (fixed-to-mobile) communications are suited for services and applications where information is disseminated to users who are not located near the source of transmission and who require seamless coverage. Wide area wireless communications are further differentiated based on whether they are one-way or two-way. An example of a one-way, broadcast transmission are the traffic reports we currently receive over AM or FM radio. A mobile traveler who requests and receives current traffic information from an Information Service Provider, is an example of two-way communications.
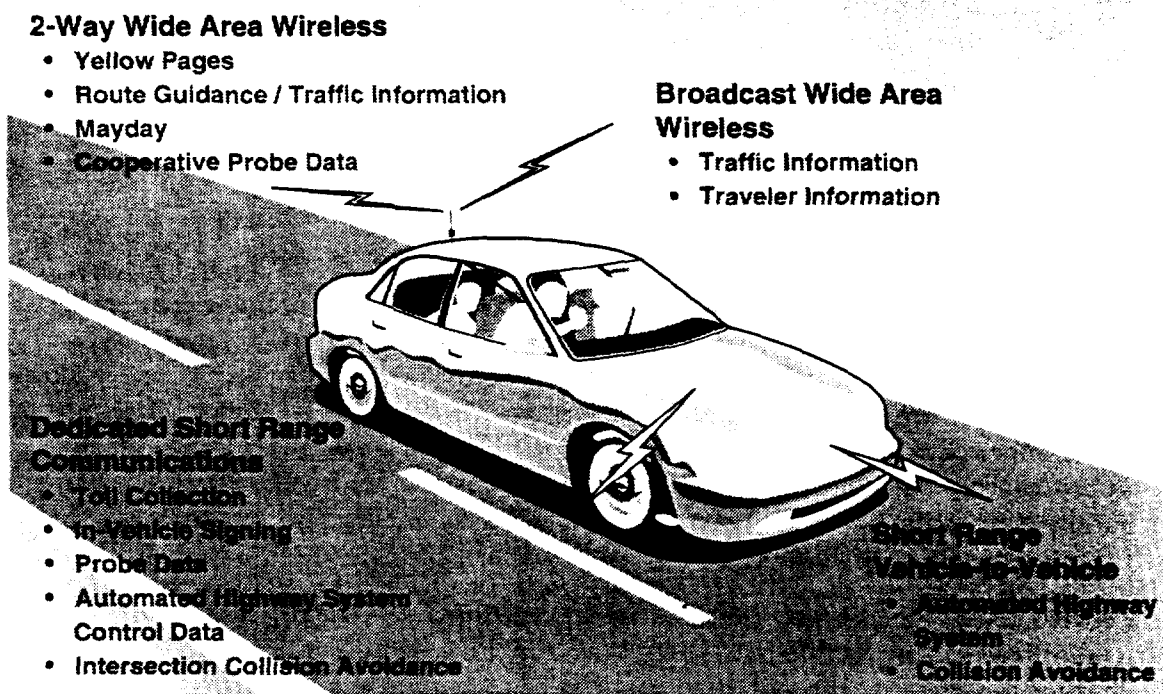
Several two-way wide area wireless technologies were assessed by the architecture team. They included Global System for Mobile Communications (GSM), Special Mobile Radio (SMR), Enhanced Special Mobile Radio (ESMR), Personal Communications System (PCS), ARDIS, RAM, Geotek, 220 Mhz, Metricom, Tetherless Access Ltd. (TAL), two-way paging, and Cellular Digital Packet Data (CDPD). Although each technology had its own strengths and weaknesses relative to addressing ITS communication requirements, all of the currently deployed systems failed to provide the ubiquitous coverage required for nationwide interoperability.

In an attempt to address the ubiquitous coverage issue, the architecture team assessed the current and emerging satellite communication technologies. Systems assessed included ORBCOMM, STARSYS, VITASAT, MSAT, Constellation, GLOBALSTAR, IRIDIUM, TELEDESIC, Ellipso, Odyssey, Skycell, VSAT, and OmniTRACS. Availability and cost of the service, coupled with the cost of the terminals, were common issues that must be addressed if satellite communication technologies are to be a viable candidate for ITS user services.

The architecture team also examined one-way, broadcast communication technologies. Technologies examined included AM subcarrier, FM subcarrier, and Highway Advisory Radio (HAR). FM subcarrier systems assessed included MitreTec's Subcarrier Traffic Information Channel (STIC), NHK's Data Radio Channel (DARC), SEIKO's High Speed FM Subcarrier Data System (HSDS), RBDS, ALERT, and Modulation Sciences, Inc.'s SCA. Issues that resulted from these assessments included the limited coverage of the currently available systems and the proprietary hardware and interfaces of the high data rate systems (HSDS, STIC, and DARC). The assessment did indicate that all of the high data rate systems would meet the capacity requirements of the ITS data flows proposed for broadcast communication services.

The second category, short range wireless, is concerned with information transfer that is of a localized interest. There are two types of short range wireless communications identified by the architecture. They are vehicle-to-vehicle and Dedicated Short Range Communications (DSRC). Vehicle-to-vehicle (mobile-to-mobile) short range wireless communications are required to support the Automated Highway System (AHS), and most likely, intersection collision avoidance implementations. The architecture team has identified the required interfaces and data flows, but has not assessed available and/or emerging communication technologies, since the AHS Consortium has several ongoing studies in this area.

Appropriate applications for DSRC (fixed-to-mobile) include toll collection, parking fee collection, roadside safety inspections, credential checks, in-vehicle signing, intersection collision avoidance, and selected Automated Highway System (AHS) communications (e.g., safety checks, access authorization, and system status updates). The architecture team assessed radio frequency (RF) and Infrared (IR) short range wireless beacon/tag communications for the DSRC requirement. Key issues relative to beacons that require further analysis and study are the required coverage and who should pay for their installation, operation, and maintenance. The communication media required to provide a full range of ITS services to the passengers of a vehicle of the future are provided below.

2-Way Wide Area Wireless
- Yellow Pages
- Route Guidance / Traffic Information
- Mayday
- Cooperative Probe Data

Broadcast Wide Area Wireless
- Traffic Information
- Traveler Information

Dedicated Short Range Communications
- Toll Collection
- In-Vehicle Signing
- Probe Data
- Automated Highway System Control Data
- Intersection Collision Avoidance

Short Range Vehicle-to-Vehicle
- Automated Highway System
- Collision Avoidance

Vehicle Communications in the Future

Some broad conclusions can be drawn from the communications assessments and analyses.

- A large set of the architecture data flows are best supported by commercially available mobile wireless data networks operated in the packet switching mode. Prominent among these today are GSM, RAM, ARDIS, and CDPD.

- Although GSM is not significantly deployed in the United States, it is extensively used in Europe and should be considered as an alternative communications service for product vendors.

- Of the new communication technologies being deployed, CDPD's technical performance has been validated through ITS-related simulation and through

operational field trials. CDPD's coverage is expected to cover the entire footprint of the cellular system, which is projected to cover 75% of the population before the end of 1997. Another version of CDPD, which extends Internet Protocol (IP) capabilities to regular AMPS cellular channels and the PSTN, called "Circuit Switched CDPD", will be used to extend CDPD service to areas that do not have the full CDPD overlay implementation. Nevertheless, some areas may never have CDPD in any form, and may transition directly to other, more advanced, cellular or PCS based packet data systems.

- RAM and ARDIS coverage is focused on the major metropolitan areas where there is significant business activity. There is little or no coverage in rural areas.

- Metropolitan area network type wireless data systems, such as systems by Metricom and TAL, can be used to access some ITS user services. One limitation is that these data systems are targeted at the non-mobile user. Because of their simplicity, these systems offer price advantages over mobile wireless data systems.

- Two-way paging (narrow band PCS) can be used for applications that are not time critical and which do not require a real time response. Particularly suitable would be messages for which a canned response would suffice.

- There are an array of satellite systems that are suitable for ITS applications. These include a variety of Little (data only) and Big (voice and data) low-earth-orbit (LEO) systems, as well as more conventional medium-earth-orbit (MEO) and geosynchronous orbit (GEO) systems. Many of these systems are not yet deployed, however they are projected to be in service within the next few years. Because of the higher costs for services and equipment, satellite systems would be most appropriately used where terrestrial alternatives are not available. Among the satellite systems, little LEO choices seem to be the most appropriate, since they are targeted specifically at short bursty data transactions.

- Service prices for two-way systems have come down in recent years, however, cost is a significant issue for the consumer, both for the communications device and the charges for service. If equipment costs were to drop to the $200 range, and more applications were to become available, a mass market could develop. This will probably take a few years. ITS is no different in this respect than other wireless data application areas. ITS applications will benefit from the developments and user acceptance trends in the broader fields of the mobile office and wireless Internet access.

- There are several broadcast media choices for one-way ITS communications. The most prominent among these are FM Subcarrier systems. A detailed quantitative assessment of the three leading high speed subcarrier systems (HSDS, DARC, and STIC) has been performed. The analysis showed that any one of them would be adequate to carry the broadcast data flows envisioned. The low speed RBDS FM subcarrier could also be used if the ITS application could live with relatively small amounts of data or long periods between updates.

- For the wide area wireless interface, the data loading results indicated that for the Urban environment in the year 2002, the largest data loads would result from the local CVO user service group, followed closely by transit and private vehicles. Private vehicle and local CVO were the largest data users, twice the rate of transit. In the inter-urban environment (suburb and inter-city), for the same time period, local CVO and transit would be the largest data users. For the inter-urban environment in 2012, local CVO remained the largest data user, followed by transit. The rural data loads were very low, with local CVO the largest user, followed by private vehicles.

- Cellular Digital Packet Data (CDPD) wireless simulation results have shown that the delay from the vehicle to the infrastructure, even in the presence of non-ITS data, and with an incident during the peak period, is very low (150 ms for ITS only; 300 ms for ITS plus non-ITS; 10% increase in the sectors affected by the incident).

- For broadcast systems, the quantitative analysis has shown that the combination of the low-rate RBDS, with the emerging high data rate FM subcarrier standard, will satisfy the ITS Architecture broadcast requirements for the foreseeable future. New broadcast techniques, including Digital Audio Broadcasting, will accommodate any long term growth.

The conclusion that can be drawn from the technology assessments and the data loading and communication system performance analyses, is that the commercially available wide area wireless (including broadcast) and wireline infrastructures, adequately meet the near term technical requirements of ITS. Deployment of ITS services will depend on these communications services being affordable. We expect that as markets evolve, existing communication technologies and infrastructure will evolve and expand to meet the growing needs.

Benefits Resulting from the Architecture

The basic benefit of the architecture is to provide a structure that supports the development of open standards. This results in the below derived benefits:

Integration: The architecture makes integration of complex systems easier. This is achieved by presenting the structure around which standards can be developed. Because of improved integration, ITS services will benefit from better availability and sharing of traveler information, such as congestion information, and better utilization of shared resources, such as roadside surveillance data.

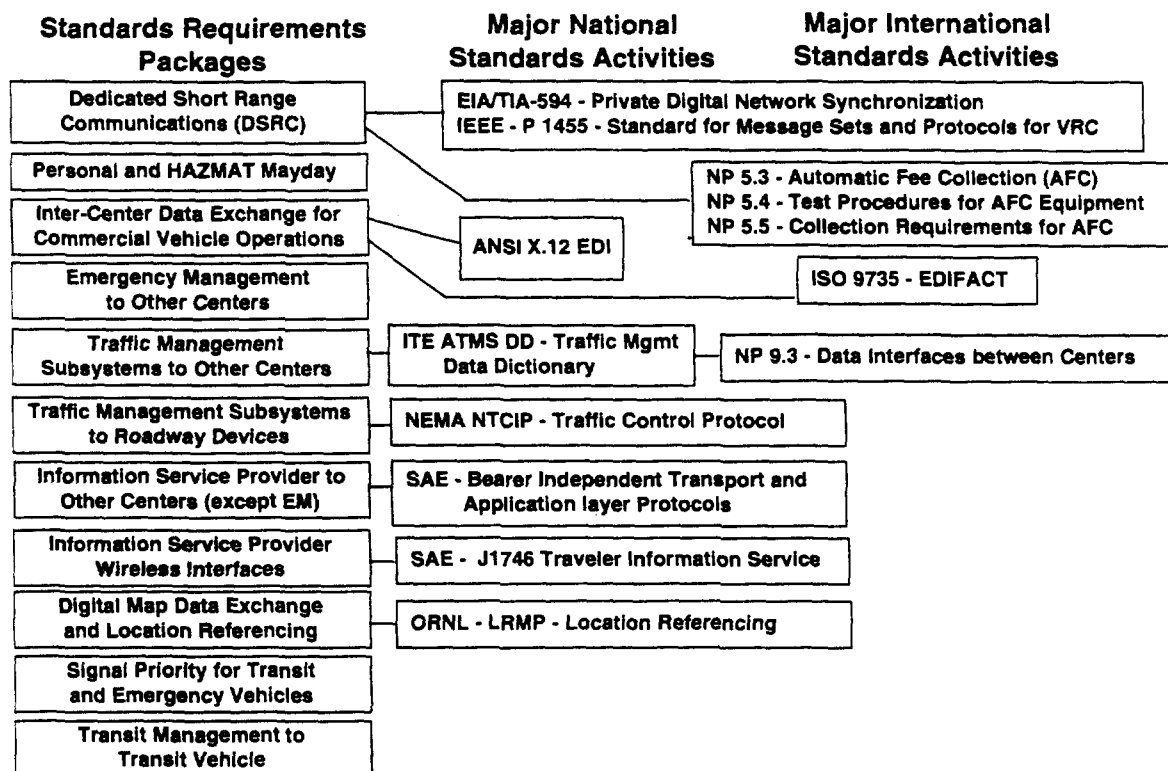**Compatibility:** The same mobile equipment will work over the entire country. Because equipment is compatible everywhere, there is a larger total market for services, resulting in more capable and cost effective products. Similarly, infrastructure systems can use standards to improve product quality and lower product costs. Future growth is enhanced by open standards being available, allowing everyone a chance to participate.

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Support for Multiple Ranges of Functionality: Because the architecture does not dictate a design, standards can be developed to support a wide range of designs or levels of functionality in deployment, providing services ranging from free to pay-for-use.

Synergy: An overused concept but in this case, well suited due to the careful methodology used in development of the architecture. The methodology began with the architecture functional requirements and then mapped common requirements into specific applications. This allows developers to support a range of applications with similar functions and thereby serve larger potential markets with their products.

Standards

The architecture structure is a means through which relatively independent standards activities can proceed with harmonious results. Because the standards will be developed based on the architecture interfaces and data flows, information that cuts across standards activities is identified. This knowledge allows standards organizations to be aware of overlapping activities. It also permits the effective coordination of activities.

Standards Requirements Packages	Major National Standards Activities	Major International Standards Activities
Dedicated Short Range Communications (DSRC)	EIA/TIA-594 - Private Digital Network Synchronization IEEE - P 1455 - Standard for Message Sets and Protocols for VRC	
Personal and HAZMAT Mayday		NP 5.3 - Automatic Fee Collection (AFC) NP 5.4 - Test Procedures for AFC Equipment NP 5.5 - Collection Requirements for AFC
Inter-Center Data Exchange for Commercial Vehicle Operations	ANSI X.12 EDI	
Emergency Management to Other Centers		ISO 9735 - EDIFACT
Traffic Management Subsystems to Other Centers	ITE ATMS DD - Traffic Mgmt Data Dictionary	NP 9.3 - Data Interfaces between Centers
Traffic Management Subsystems to Roadway Devices	NEMA NTCIP - Traffic Control Protocol	
Information Service Provider to Other Centers (except EM)	SAE - Bearer Independent Transport and Application layer Protocols	
Information Service Provider Wireless Interfaces	SAE - J1746 Traveler Information Service	
Digital Map Data Exchange and Location Referencing	ORNL - LRMP - Location Referencing	
Signal Priority for Transit and Emergency Vehicles		
Transit Management to Transit Vehicle		

Standards Supporting Architecture Standards Packages

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Standards development is of interest to nearly all organizations involved with the deployment of ITS. It is anticipated that product developers, communication providers, and private service providers will play an equal role in standards activities with local, regional, state, and federal public infrastructure agencies. It may be to their advantage to become involved with international activities as well, since significant efforts are underway outside the United States as indicated in the above figure. In particular, the adoption of common standards with Canada and Mexico would be beneficial to all three countries.

The architecture has identified 11 key standards areas that are relatively independent. The figure above indicates the standards packages along the left hand column and the current standards activities that are already addressing some of the key standards areas on the right. Certain areas are not currently covered by any significant activities and will require new efforts. For each of the standards packages, a detailed list of architecture data flows is provided so that standards organizations can readily apply the architecture to their efforts.

DEPLOYMENT OF ITS

The Implementation Strategy defines a series of steps that encourage efficient deployment of architecture compatible systems. These include:

- Identification of basic building blocks that apply to most ITS deployments,
- Focus on low-risk early deployments most relevant to near-term problems,
- Further encourage private sector participation in ITS deployment,
- Parallel advancements in service and system integration over time.
- Recommended Strategic Actions.

Identify ITS Building Blocks. During the course of the program, it became apparent that some of the original user services were too broad in scope to be convenient in planning actual deployments. Accordingly, a finer grained breakdown of ITS services have been defined in what are called *market packages*. These market packages listed below are tailored to fit - separately or in combination - real world transportation problems and needs. For example, Traffic Control has been broken into *Surface Street Control*, which is typically under the local jurisdiction, and *Freeway Control*, typically under State Transportation Agency control. Many market packages are also incremental so advanced packages can be efficiently implemented based on earlier deployments.

Traffic Management	Traveler Information	Transit Management
• Network Surveillance	• Broadcast Traveler Information	• Transit Vehicle Tracking
• Probe Surveillance	• Interactive Traveler Information	• Transit Fixed-Route Operations
• Surface Street Control	• Autonomous Route Guidance	• Demand Response Transit Operations
• Freeway Control	• Dynamic Route Guidance	• Transit Passenger and Fare
• HOV and Reversible Lane	• ISP Based Route Guidance	Management
Management	• Integrated Transportation	• Transit Security
• Traffic Information Dissemination	Management/Route Guidance	• Transit Maintenance
• Regional Traffic Control	• Yellow Pages and Reservation	• Multi-modal Coordination
• Incident Management System	• Dynamic Ridesharing	
• Traffic Network Performance	• In Vehicle Signing	**Advanced Vehicles**
Evaluation		• Vehicle Safety Monitoring
• Dynamic Toll/Parking Fee Mgmt	**Commercial Vehicles**	• Driver Safety Monitoring
• Virtual TMC and Smart Probe	• Fleet Administration	• Longitudinal Safety Warning
• Emissions and Environmental	• Freight Administration	• Lateral Safety Warning
Hazards Sensing	• Electronic Clearance	• Intersection Safety Warning
	• Electronic Clearance Enrollment	• Pre-Crash Restraint Deployment
Emergency Management	• International Border Electronic	• Driver Visibility Improvement
• Emergency Response	Clearance	• Advanced Vehicle Longitudinal
• Emergency Routing	• Weigh-In-Motion	Control
• Mayday Support	• Roadside CVO Safety	• Advanced Vehicle Lateral Control
	• On-board CVO Safety	• Intersection Collision Avoidance
ITS Planning	• CVO Fleet Maintenance	• Automated Highway System
• ITS Planning	• HAZMAT Management	

ITS Market Packages

Recommend Early Deployments. The market packages are interrelated and are also influenced by the availability of basic supporting infrastructure, the evolution of technology, the emergence of industry standards, the institutional context of implementation, and market demand. It is difficult to predict when many of these factors will be resolved. Instead, the strategy suggests early deployments that are not dependent on technology advances or institutional change and it leaves room for a competitive environment in which to advance transportation technologies. *Early Market Packages* are the subset of market packages that appear to be early winners due to a promising combination of low risk implementation characteristics, developing public and private markets, and tangible system or user benefits. Market packages that best satisfy the above criteria include: *Surface Street Control, Freeway Control, Dynamic Toll Management, Transit Vehicle Tracking, Transit Operations, and Electronic Clearance.*

The nine elements identified by the Intelligent Transportation Infrastructure initiative further prioritize those early market packages that are oriented towards public infrastructure support for major metropolitan areas. This provides additional near-term focus for the strategy.

Encourage Private Sector Participation. An attempt has been made to structure many of the services so that the collection of user fees is practical in order to attract private capital. Where the prospect of user fee revenue is inadequate to attract this investment, the possibility of contractual arrangements with public sector agencies